REQUEST FOR PROPOSAL

For the

NASA SLR2000 GIMBAL and CONTROLLER

March 10, 1999

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DRAFT
Statement of Work for Comment
Specifications and Characteristics for NASA SLR2000 Gimbal

COMMENTS DUE BACK 09 APRIL 1999

1.0 Scope & Background

AlliedSignal Technical Services seeks to purchase a gimbal and control system for the NASA SLR2000 Satellite Laser Ranging System. The SLR2000 system is an autonomous, unmanned satellite laser ranging station, designed to track earth orbiting artificial satellites 24 hours a day, except during inclement weather. The gimbal will support a telescope and enclose a mirror assembly that optically couples the laser Transceiver to the telescope. Both the gimbal and telescope are enclosed in a ten-foot diameter dome with shutter, atop a twelve-foot square building.

The scope of this effort includes the design, fabrication, testing, delivery, training, and documentation for a gimbal and control system meeting or exceeding the listed specifications. Bidders are to include a price and delivery for one gimbal and controller and a price for replication of eight additional gimbals and controllers.

Figures 1-1 and 1-2 are conceptual type drawings of the system. Figure 1-1 shows an overview of the SLR2000 system with the gimbal/telescope in a yoke type configuration, while Figure 1-2 shows an off-axis type gimbal/telescope arrangement. Either arrangement is acceptable to the customer but cost and system performance shall determine the final selection.

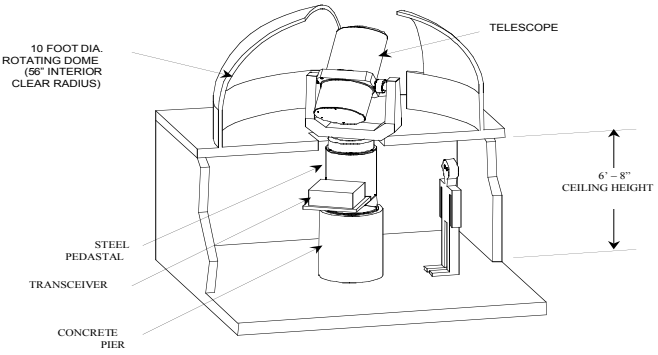
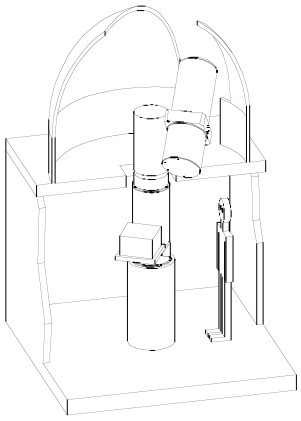


Figure 1-1 SLR2000 System Overview

1.0 Scope & Background (Cont.)



Possible Variation of Gimbal Design
Off – Axis Gimbal / Telescope Arrangement
Figure 1-2

1.1 System Description Summary Highlights

Operation	- Unattended 24 hour operation
Maintenance	- Minimum four-month mean time between technical maintenance/service visits
Operational Lifetime	- 20 Years
Gimbal Operating Environment	- 20° to 120° F - 5 to 98% RH (no precipitation) - Salt, fog, sand, dust, pollen - Dome shutter closed during periods of precipitation, high winds, or when external temperatures are outside operational limits
Controller Operating Environment	- Climate controlled 72° +/- 3° F - Dehumidified - Thermal barrier between ceiling & dome floor

1.1 System Description Summary Highlights (Cont.)

Gimbal Support	- Gimbal mounted on a steel tube anchored to a concrete pier
Ranging Information	- Laser fire rate is 2kHz - Laser beam divergence 10 arcseconds (Full Width between $1/e^2$ intensity points) - Satellite altitudes lie between of 400Km and 20,000Km above mean sea level and tracks are from horizon to horizon - Initial acquisition of satellites is based on precise pointing angles from Tuned Inter Range Vectors (open loop with no feedback from the satellite) - Tracking point angles are refined from feedback by customer supplied quadrant detector - Mount pointing errors are modeled using at least one full star calibration per day with hourly single star updates - Horizontal ranging to ground targets is used to determine system delay. Targets may be located as low as 5 degrees below the gimbal horizon.

2.0 Gimbal Structure

The contractor shall design, fabricate, assemble, test, and deliver a gimbal structure to the minimal acceptable specifications given in Table 2-1. For gimbal payload specifications reference Table 2-2 and Figure 2-1 which give the geometry and mass properties of the telescope.

2.1 Mechanical Description

The gimbal system will support the telescope payload and enclose the shared transmit/receive optical path. The trunnion box around the telescope structure shall provide the mechanical interface to the gimbal. This trunnion can be built by the contractor or provided by the customer. The responsible party (contractor or customer) will provide gimbal or telescope interface requirements for the trunnion.

Table 2-1 Gimbal Specifications

Slew Rate	- 30 deg/sec azimuth - 20 deg/sec elevation
Maximum tracking rate	- ≥ 5 deg/sec both axes
Minimum tracking rate	- Sidereal
Maximum load acceleration	- 5 deg/sec^2 both axes
Position resolution	- +/- 0.3 arcsecond

Table 2-1 Gimbal Specifications (Cont.)

Transducer accuracy	- +/- 1.0 arcsecond
Axis Wobble	- 3 arcseconds maximum repeatable error
Axis Orthogonality	- 5 arcseconds maximum repeatable error
Total Travel	- Azimuth: continuous, through the use of slip-rings. The number of rings for customer signals - TBD - Elevation: -5 to 185 degrees
Optical Path	- Environmentally sealed volume for optics - Minimum centered 3-inch clear aperture - Total optical beam deviation less than +/-6 arcseconds between the azimuth and elevation axes under dynamic tracking operation - Fold mirrors provided by the customer - Windows provided by the customer - Mirror and window mounts supplied by the contractor - Free of oils, grease, and lubricants - Optics isolated from bearing contaminants - Partitioned yoke to isolate optics from wiring and motors - Interior surfaces are black for stray light control. Aluminum surfaces shall be hard black anodized. Other metal surfaces shall be painted black (baked, low-outgassing) - Sealed access panels for fold mirrors and windows - Purge port and vent valve supplied by contractor - Mounting holes for desiccant cannister and dry air supply to be supplied by contractor - Desiccant cannister and dry air supply to be supplied by customer
Telescope Trunnion	- Can be provided by the contractor or customer
Safety	- A combination of limit switches and decelerator type shocks on the elevation axis to prevent telescope damage
Stow Pins	- Incorporate in each axis, to be used for transportation and maintenance purposes (Azimuth-one position, Elevation-two positions 0 and 90 degrees)
Brakes	- Incorporate manual friction type in each axis

Table 2-1 Gimbal Specifications (Cont.)

Gimbal Base	- Attachment base bolt pattern TBD - +/-10 arcseconds resolution bubble level mounted on the azimuth axis - Leveling mechanism shall provide +/-10 arcseconds leveling capability (can be provided by the customer or by the contractor)
Gimbal Surfaces	- Exterior finish shall be white; type selected to maximize durability and minimize thermal gradients - All surfaces shall have a smooth finish - All surfaces shall be protected from rust
Component Specification	- Must meet environmental specifications listed in section1.1

Table 2-2 Telescope Geometry and Mass Properties

Trunnion Box width	- 24 inches
Rearward extension	- 23 +/- 2 inches
Telescope length	- 63 inches
Weight	- 188 pounds
Center of gravity	- within 1 inch of the center of rotation of elevation axis
Rotation Inertia (elevation)	- 8100 lb-in^2
Rotation Inertia (azimuth/telescope vertical)	- 1800 lb-in^2
Telescope Stiffness	- 100 Hz or greater

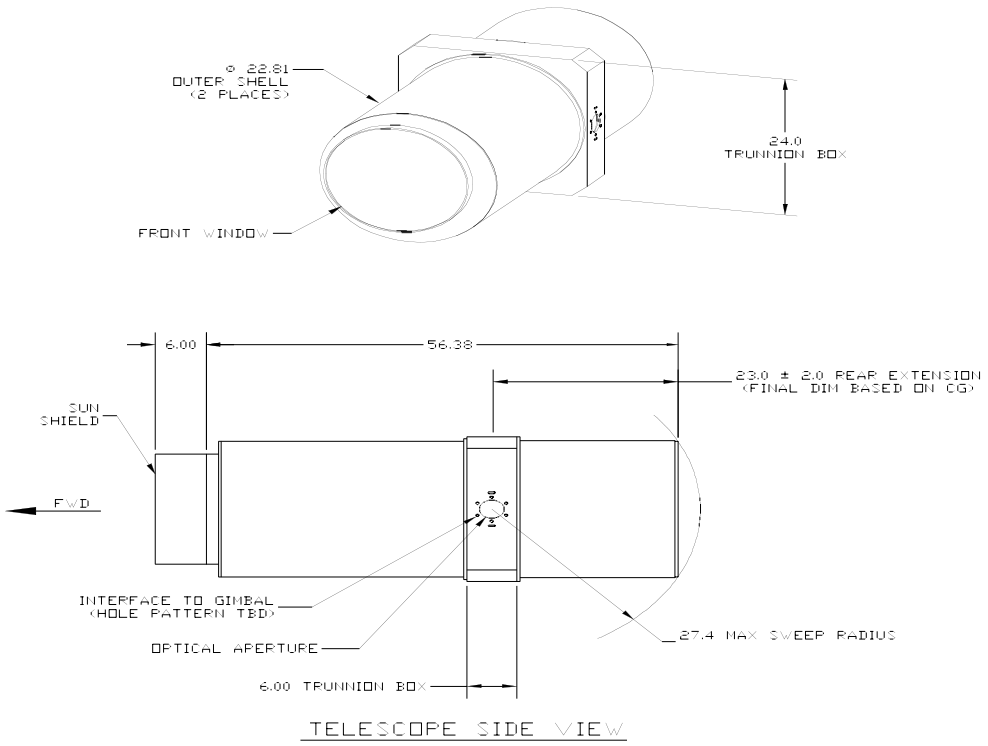


Figure 2-1 Telescope Exterior Dimensions
(Dimensions in inches)

2.2 Gimbal Leveling System

The gimbal assembly and the laser transceiver will be mounted onto a hollow steel pedestal that mounts onto a concrete pier (reference figure 1-1). A mechanical leveling system, located between the base of the gimbal and the steel pedestal, will have the capability of leveling the gimbal to within +/-10 arcseconds and will provide the mechanical rigidity necessary to support the mass and torque of the gimbal system. The contractor may design and fabricate this leveling system or it will be provided but the contractor must provide a +/-10 arcseconds bubble level on the gimbal to be used during the gimbal leveling operation. In addition, the contractor shall provide the maximum reaction forces at the gimbal base mounting points and bolt pattern within 30 days after the contract award date. The customer will design the gimbal pier/pedestal structure from this data.

2.3 Optical Path

Provision shall be made for mounting folding mirrors to provide an optical path from the telescope to the transceiver. Two optical windows, one centered on each gimbal axis, shall seal the yoke interior. The azimuth drive shall provide clearance for a plenum tube that will pass through the azimuth drive and extend below the gimbal as much as 15 inches. Reference Figure 2-2, which is a preliminary design approach for sealing the optical path to keep moisture and contaminants off the optical surfaces and provide thermal isolation between the gimbal and building interior. Windows and mirrors will be provided to the contractor. The contractor shall provide the window and mirror mounts.

Removable access panels shall be provided for each of the mirror and window assemblies. The access panels shall be large enough to allow for adjustment or removal of the complete assemblies. Panels shall be located so that they provide access when the gimbal is installed at the facility. The panels, along with the two windows, shall environmentally seal the yoke interior (water tight and dust-proof). All exterior seams in the optical path section of the yoke shall be environmentally sealed.

The total optical deviation of a beam through the yoke (due to combined thermal, static, and dynamic mechanical deflections) shall not exceed +/-6 arcseconds. This includes deflections of the yoke-mounted mirrors (for which an arcsecond of mechanical deflection may produce up to 2 arcseconds of optical deviation) and deflections of the azimuth and elevation bearings and mounts.

The interior of the yoke shall be black for stray light control as well as cleanliness. Hard black anodize is required for aluminum components.

The yoke structure and its covers shall be free of all oils, grease, lubricants, and other volatile and non-volatile contaminants prior to delivery. In particular, there shall be no interior blind screw holes, or internal areas or pockets, which are inaccessible for cleaning. The azimuth and elevation bearings, motors, encoders, and harness shall be isolated from the yoke interior volume, which contains the optics.

A replaceable desiccant - breathing canister (customer supplied) shall be mounted on the yoke for pressure equalization and a clean, dry environment for the optics. A yoke purge port and vent valve (contractor supplied) shall also be incorporated.

2.3 Optical Path (Cont.)

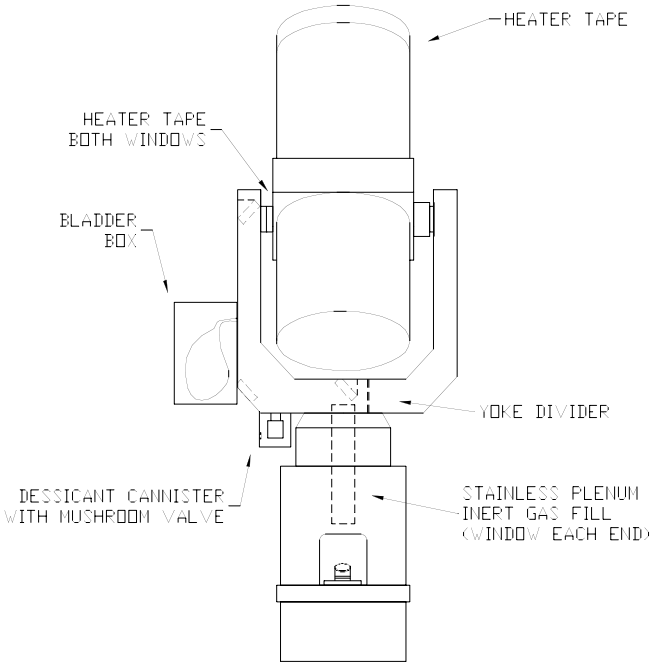


Figure 2-2 Sealed Optics Approach

2.4 Axis Drive and Rotation

Direct drive DC torque motors shall be incorporated and coupled directly to each axis to provide motion. Azimuth rotation shall be continuous through the use of slip-rings. The customer requires slip-rings to provide power to heat tape on certain optics and spare rings shall be provided for signal redundancy. The total number of slip-rings to be provided to the customer is TBD. Elevation rotation shall be from –5 degrees to 185 degrees to allow for optical alignments. Also, mechanical limit switches and decelerator type stops shall be incorporated in the elevation axes to prevent instrument damage in the event of a mount run-away situation.

Manual friction brakes shall be provided on each axis and stow pins shall be incorporated that lock each axis in a fixed position. The azimuth axis shall have one stow pin (no specified position), while the elevation shall have two stow pins, one to lock the axis at 0 degrees and the other to lock the axis at 90 degrees.

2.5 Encoder and Tracking

Each axis position shall be determined from inductosyn type position transducers coupled directly to each axis to provide at least +/- 0.3 arcsecond resolution (22 bits). This shall be an absolute type encoder system and true position can be determined on a power-up without a home position requirement. The axis wobble and orthogonal errors shall be repeatable such that the gimbal with payload shall be able to maintain the tracking specifications given in section 3.0 over the specified tracking and acceleration rates.

2.6 Dome Dimensions

The SLR2000 facility will be comprised of a 12 by 12 by 7 foot insulated building, with a 10-foot diameter astronomical dome and 2 foot spacer ring placed on top of the roof. The atmosphere inside the building will be controlled using a basic heating and air conditioning system. The atmosphere inside the dome will be maintained at the ambient temperature and will be controlled to minimize condensation and to keep the temperature between the 20 degrees to 120 degrees Fahrenheit specification (reference section 1.1). The dome will house the telescope and gimbal but will be open only during periods of satellite tracking or horizontal ranging. The telescope will be positioned inside the dome such that its aperture will have an unobstructed view out of the slit (reference Figure 2-3) throughout a –5 degrees to 90 degrees range of elevations. The inside of the dome is clear of obstructions within a 56" radius from its center everywhere above the floor.

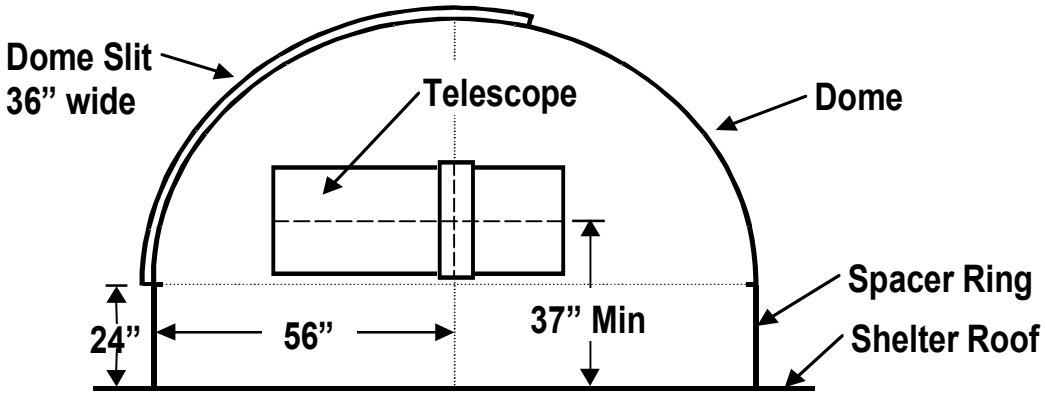


Figure 2-3

2.7 System Survey Considerations

This system, which will be used for precise geodetic measurements, requires that the intersection of the azimuth and elevation axis of the gimbal be accurately located with respect to nearby survey ground monuments. To facilitate this effort, the contractor shall provide a scribe point that marks the center of rotation of the elevation axis and is visible on the exterior of the system. For the azimuth axis (if the contractor provides the trunnion), the contractor shall locate a capped 5/8"-11 UNC threaded 1 inch deep hole directly above the center of azimuth rotation on top of the telescope trunnion plate. This stud will be used to attach survey instruments that will allow the measurement of distances from the center of rotation of the gimbal system to nearby ground targets.

3.0 Control Electronics

The gimbal system controller shall be enclosed in one standard 19-inch rack mountable type chassis. The controller will contain the servo loop controls, the servo amplifiers, and the interface to the customer computer. Either a parallel or serial type interface is acceptable between the customer computer and the controller.

The control electronics and software shall be designed to allow the gimbal to track at rates from sidereal to ≥ 5 degrees/second, while maintaining an error between the command position angle and the actual position angle as read from the encoders to be ≤ +/-1 arcsecond. The system shall be able to smoothly change accelerations which will vary from – 5 deg/sec^2 to + 5 deg/sec^2. This margin of error must be maintained with a comparison of the angles read at a rate of 2 kHz. If the angles cannot be read at this high rate an analog signal which represents this error can be used to demonstrate this tracking performance. Command rate requirements of the gimbal from the customer's computer shall be no greater than 100 Hz.

The optimum command type, command rate, and angle position read rate from the customer computer will be dependent on the contractor's approach in achieving the command angle vs. actual angle requirement described above (reference specifications Table 3-1).

The contractor shall provide the customer with sufficient information to understand the closed loop servo system and shall provide technical assistance as necessary with the software interface. User software shall allow adjustment of control parameters from default parameters and allow easy reversion to the default parameters. Also, to be bid as an option, the contractor can provide a software simulator, which is a control model of the gimbal system. The model shall support the adjustment of all control parameters.

3.0 Control Electronics (Cont.)

Table 3-1 Control Electronics Specifications

Tracking performance	- Command vs. actual encoder position error ≤ +/-1 arcsecond with angles read at a 2 kHz rate.
Customer Computer I/O:	
Communications	- Parallel or Serial (determined by the contractor)
Command type	- Dependent on contractor's requirement to maintain the command vs. actual angle tracking performance specification.
Command rate	- Dependent on contractor's requirement to maintain the command vs. actual angle tracking performance specification. The rate can be between 20 to 100 Hz but must be an integer factor of 2000.
Angle read rate	- Dependent on contractor's capability to maintain the command vs. actual angle tracking performance specification. For routine operations the rate must be less than 1 kHz and an integer factor of 2000. However, for acceptance tests purposes, system must be capable of demonstrating the pointing requirements at the 2 kHz rate.
Position Resolution	- Minimum 22 bits per axis
Chassis	- 19 inch standard rack mount - Front panel power 'on' indicator
Power	- 120Vac 50-60 Hz.
Chassis Location	- Inside environmental controlled building area - Within 20 feet of the gimbal
Cable/connectors	- Must meet environmental specifications listed in section 1.1 - Customer shall provide pin-out to computer connector
Components	- Must meet environmental specifications listed in section 1.1

4.0 Documentation

The contractor shall develop and furnish both hardware and software system manuals. Three hard copies of each manual with a back-up copy of all manuals on a Cd-rom are to be provided to the customer.

4.1 Hardware Documentation

A Technical Manual shall be provided that details all user functions, checkout procedures, alignment procedures, and principles of operation and maintenance. Also required are all assembly drawings, schematics, parts lists and a recommended spares list.

4.2 Software Documentation

A Software Manual shall be provided and include a description of the software interface to the servo controller, a description of the algorithms used in servo control, how the customer uses the servo interface software in their applications, and the software test reports. Preliminary software documentation shall be provided 3 months prior to acceptance tests at the contractor's facility, to allow the customer to begin software development.

5.0 Acceptance Requirements

Two levels of acceptance testing shall be conducted. The first level shall be conducted at the contractor's facility to allow the customer to interface with the gimbal system for customer software development purposes as well as performance testing of the contractor's gimbal. The second level shall be conducted at the customer's facility to perform tests which will more closely represent system operations.

5.1 Acceptance Tests at the Contractor's Facility

Detailed acceptance testing shall be performed at the contractor's facility in accordance with an acceptance plan developed by the contractor and approved by the customer (schedule for the plan TBD). Gimbal acceptance tests involving a computer interface will use the contractors' computer, interface, and interface software. The customer, however will supply necessary equations and/or code for the contractor to simulate satellite tracking.

Minimum testing will demonstrate the following:

a) Azimuth and elevation position repeatability (number of data points TBD, reference Table 2-1).
b) Total optical beam deviation +/-6 arcseconds maximum between the azimuth and elevation axes under dynamic tracking conditions (number of data points TBD, reference section 2.3).
c) Command versus actual position error ≤ +/-1 arcsecond using simulated satellite tracks supplied by the customer (2000 points-per-second read rate, reference section 3.0).

To perform these acceptance tests the customer will provide a mass simulator, which will be identical to the final telescope in dimension, stiffness, inertia, and weight. Also at this time customer-supplied software and hardware gimbal interfaces will be tested and verified. The customer will work with the contractor to resolve any issues with customer-supplied software or hardware. The test results shall be documented, delivered, and accepted by the customer prior to delivery of the gimbal to the customer.

5.2 Acceptance Tests at the Customer's Facility

Final acceptance testing will occur at the customer's facility. An acceptance plan will be developed by the customer and agreed to by the contractor (schedule for the plan TBD). Minimum testing will include position repeatability and command versus actual position errors using simulated satellite tracks, and star calibrations. The customer will perform acceptance tests using customer-supplied software and hardware gimbal interfaces.

6.0 Training

The contractor shall provide training, for two to three customers at the contractor's facility, in the operation and maintenance of the gimbal hardware, electronics and software systems. The occurrence of the training will be determined at a later date.

7.0 Design Reviews and Progress Reports

Following the contract award there will be a preliminary and a final design review between the customer and the contractor on a mutually acceptable date at the customer's site. At these times specifications will be reviewed and clarified where necessary and a final design will be implemented. Also at these times, the schedule will be updated to chart and review the contractor's progress until the time of system delivery. At the minimum, it is expected that there will be monthly technical progress reports.

8.0 Maintenance Program

The customer expects the contractor's system to see continued use over the next 20 years. As a result, the contractor shall provide a scheduled maintenance plan for the entire system and the expected life cycle of all major mechanical parts.

9.0 Schedule for Key Deliverables

The following are delivery times for key items listed in this statement of work:

- Delivery of the gimbal system to the customer is 6 to 9 months after the award of the contract.
- Pedestal height and over all optical path length delivered within 30 days of the contract award.
- Gimbal mounting reaction forces and base footprint (reference section 2-2) delivered within 30 days of the contract award.
- The preliminary software documentation shall be delivered 3 months prior to acceptance tests at the contractor's facility

10.0 Technical and Cost Proposal

The contractor shall respond to this Request for Proposal (RFP) with a Technical and Cost Proposal for the price and delivery of one gimbal and controller and a price for replication of eight additional gimbals and controllers. The Technical Proposal shall clearly respond to all requirements of the RFP as well as identify any areas of concern, including schedule, which the contractor may have. The Cost Proposal shall identify all costs, which the customer will incur from the contractor. In addition, the contractor shall provide separate cost information for the following: trunnion, leveling mechanism, software simulator, spare parts and training. Should the contractor determine that certain specifications could be adjusted to reduce the cost of the effort, but still comply with the objective of the RFP, the contractor shall contact the technical contact identified in the RFP to discuss alternatives before providing the proposals.

11.0 Warranty

The contractor's warranty for the gimbal system shall be for a period of one year from the date of acceptance at the contractor's facility.

12.0 Points of Contact

Questions of a contractual nature are to be directed to the following:

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